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Green school outdoor environments, greater equity? Assessing environmental justice in green spaces around Dutch primary schools

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HIGHLIGHTS

- First nationwide assessment of inequalities in green school outdoor environments.
- Greener school outdoor environments tended to be in wealthier neighborhoods.
- No urban–rural differences in green school outdoor environments.
- Gaps in existing subsidy schemes for schoolyard greening leave some children behind.
- We advocate national green space justice strategies that reach all schoolyards and every child.

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ABSTRACT

Green spaces around schools contribute to children's health and wellbeing. However, only a few studies have examined whether green space provision around schools in urban and rural areas are equally available across socioeconomic groups. We assessed whether and to what extent the green space provision of public primary schoolyards differs cross-sectionally across demographic and socioeconomic neighborhood profiles in the Netherlands. A fine-grained measure of green space (e.g., lawns, hedges, and trees) was applied to 5,773 school locations centering buffers at 50 m, 100 m, and 500 m. Fitting spatial lag regression models to the data, our results showed robust and inverse associations between available green school outdoor environments and low-income and less-educated neighborhoods. The percentage of non-Western migrants was positively associated. No evidence showed greenness around schools differing across levels of urbanization; however, schools with subsidy schemes supporting schoolyard greening tended to be greener. Our overall findings highlight socio-economic disparities in green school outdoor environments across the Netherlands. To bridge this gap in environmental justice, we advocate for each child to have the ability to benefit equally from schoolyard green spaces by enabling more comprehensive greening subsidy schemes.

1. Introduction

Multiple benefits for human health (Hartig, Mitchell, De Vries, & Frumkin, 2014; Remme et al., 2021; van den Bosch & Sang, 2017) and climate resilience associated with green spaces (e.g., trees) are being established (Matthews, Lo, & Byrne, 2015; Rutt & Gulsrud, 2016; Veerkamp et al., 2021). Tentative results from epidemiological studies are finding green space-related health-supportive effects on children's mental health (Vanaken & Danckaerts, 2018), behavioral (Sakhvidi et al., 2022) and cognitive development (Dadvand et al., 2015), and academic performance (Kweon, Ellis, Lee, & Jacobs, 2017).

Given the mounting evidence for the health benefits of green spaces, children should ideally incorporate substantial green space exposure into their daily lives. In practice, however, it appears that over time the overall population of children is gradually spending more time exposed to grey built environments (e.g., non-natural built-up infrastructures such as streets and buildings), limiting their opportunities to experience green spaces (Chawla, 2015; Danks, 2010). Environmental justice scholarship has established that environmental amenities are not equitably distributed (Jennings, Johnson Gaither, & Gragg, 2012; Mohai, Pellow, & Roberts, 2009). This is exemplified in the dimensions of distribution and access by the geographically non-equitable provision of

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green spaces in urban environments (Shao, Liu, & Tian, 2021). As a result, socially disadvantaged populations are disproportionally exposed to environmental hazards (e.g., air pollution) (Mohai et al., 2009; Shao et al., 2021).

Numerous studies have documented the presence of disparities in residential green space exposures across population strata (Ferguson, Roberts, McEachan, & Dallimer, 2018; Wolch, Byrne, & Newell, 2014). Such scholarship found that low-income earners and minority groups tended to have poorer green space access (Landry & Chakraborty, 2009; Schüle, Hilz, Dreger, & Bolte, 2019); their green spaces were also often of lower quality, were less well maintained, and were less safe (Rigolon, Browning, & Jennings, 2018) compared to those members of higher socioeconomic strata and privileged majority groups (‘multi jeopardy’) (Hoffimann, Barros, & Ribeiro, 2017). Those living in low-income neighborhoods or neighborhoods with substantial minority populations are also less likely to use outdoor green spaces (Wen, Zhang, & Harris, 2013). However, in some cases, scholars have reported that minority or low-income groups are favored in terms of green space provision (Engelberg et al., 2016). Given these differing findings, critical geographical assessments of green space provision should be made without reference to urban areas’ socioeconomic profiles (Hoffimann et al., 2017).

Children spend most of their daily lives in school (Brons, Bolt, Helbich, Visser, & Stevens, 2022). Thus, it seems imperative to integrate nature-oriented design into schoolyards to provide opportunities to enhance children’s day-to-day exposure to green spaces (Bikomeye, Balza, & Beyer, 2021; Van Dijk-Wesselius, Maas, Hovinga, Van Vugt, & Van den Berg, 2018). Due to inequitable access to green space in disadvantaged neighborhoods, some previous studies have speculated that greening schoolyards (Bolte, Tamburlini, & Kohlhuber, 2010; Feng & Astell-Burt, 2017) may contribute to greater health equity (Jennings et al., 2012; Lovell, White, Wheeler, Taylor, & Elliott, 2020). However, the available empirical evidence is inconsistent, with some studies finding inequalities in green school outdoor environments (Fernández, Pérez-Silva, & Villalobos-Araya, 2022), others finding null associations (Baró, Camacho, Del Pulgar, Triguero-Mas, & Anguelovski, 2021; Zhang, Martin, Stevenson, & Yao, 2022).

Several reasons may contribute to these contradictory results. First, studies on environmental green space injustice among children have typically been conducted based on the assumption that the place of residence is the only exposure location (Casey, James, Cushing, Jesdale, & Morello-Frosch, 2017; Landry & Chakraborty, 2009; Rigolon et al., 2018; Wen et al., 2013) rather than other activity spaces, such as school (Baró et al., 2021; Requia et al., 2022). However, the location of childrens’ schools likely differ from their home locations, for example, in terms of their demographic and socioeconomic compositions.

Second, the observed inconsistencies in the findings might reflect differences in school sizes and financial resources, factors that remained largely unexamined in earlier studies (Baró et al., 2021). Schools with more constrained financial resources are often located in neighborhoods of lower socioeconomic status (Owens & Candipan, 2019). Provision of selective greening subsidies of schoolyards, or a lack thereof, to resource-constrained schools might thus either minimize or reinforce inequalities in the provision of green spaces (Giezen & Pellerey, 2021).

Third, while several studies from the Anglosphere (e.g., United Stated, United Kingdom, Australia) have been published (Kweon et al., 2017; Rigolon et al., 2018; Zhang et al., 2022), apart from the United Kingdom, European studies on this topic are comparatively underrepresented. The transferability of these findings is hampered due to differences in educational systems, and patterns of school location, among other things. Although a few Dutch studies have focused on selected cities (e.g., Amsterdam, The Hague) (Giezen & Pellerey, 2021; Van Dijk-Wesselius et al., 2018), none have included a national assessment. Such national assessments are, however, relevant because of the possibility of within-country differences (e.g., urban vs. rural areas) in green schoolyards.

We are unaware of any previous nationwide study that has evaluated whether and to what extent there is population-wide equity in green school outdoor environments. To fill this need of evidence, we addressed the abovementioned concerns by examining the associations between green space around schools and neighborhood-level socioeconomic status and ethnic composition at primary schools across the Netherlands. Our hypotheses were threefold: First, we expected that green school outdoor environments were less prevalent in neighborhoods of lower socioeconomic status than in well-off neighborhoods. Second, we hypothesized that green school outdoor environments were inversely related to urbanicity. Third, we anticipated that the regionally implemented green schoolyard subsidies would effectively yield greener school environments than those without incentives or preparation.

2. Materials and methods

2.1. Study area

We conducted a nationwide, cross-sectional study in the Netherlands, where attending school is mandatory for children aged 5–16. In the Dutch education system, parents and guardians are expected to enroll and start their children in primary school on their fourth birthday, with attendance becoming mandatory after their fifth birthday. While most children attend primary school within their neighborhood, parents may also consider a school outside that neighborhood. A Dutch global positioning system-based study reported a median school commuting distance of approximately 260 m for active modes (i.e., walking and cycling) and 400 m across all modes of transport (Helbich, 2017).

The daily time spent in school increases with age but also depends on local school opening hours. For example, for ages 4 and 5, school attendance is generally between 8:30 to 14:00, five days a week. Children spend, on average, about 40 min per day on the schoolyard (Dessing et al., 2013). While all public schools receive equal government funding, responsibility for maintaining public schoolyards has been devolved to local school boards (Overheid Netherlands, 2005).

2.2. School data

Locational data for 6,092 public primary school addresses were obtained from the education database (’Dienst Uitvoering Onderwijs’ [DUO]) for April 2022. As summarized in Fig. 1, schools with missing locational data, attribute data, and privacy-protected data (i.e., when $<$ 5 children participated in the progress test) were removed from the analyses. The remaining addresses were georeferenced employing ESRI’s ArcGIS World Geocoding Service. Schools’ main entrances were geocoded as their addresses. In total, 5,773 primary schools were included in our analyses.

We also identified the areal units within which each school was located using the most detailed neighborhood data (i.e., the ‘buurt’ level). On average, such a neighborhood is 258 ha (standard deviation [SD] $\pm$ 548). Neighborhoods of such small sizes are typically relatively homogenous regarding their population compositions and living conditions. We deemed the ‘buurt’ level suitable for our analytical purpose because catchment areas of primary schools mostly align with the neighborhoods within which they are located. There were approximately 13,600 neighborhoods in 2019, with a mean of 0.44 schools per area (SD $\pm$ 0.77).

2.3. Green school outdoor environments as the outcome variable

Green school outdoor environments resemble nature in the broadest sense (Bell & Dyment, 2008). Guided by previous studies (Baró et al., 2021; Kuo, Browning, Sachdeva, Lee, & Westphal, 2018; Kweon et al., 2017), we assessed green spaces in each school’s environs. Small-scale green spaces can only be captured to a limited extent by available

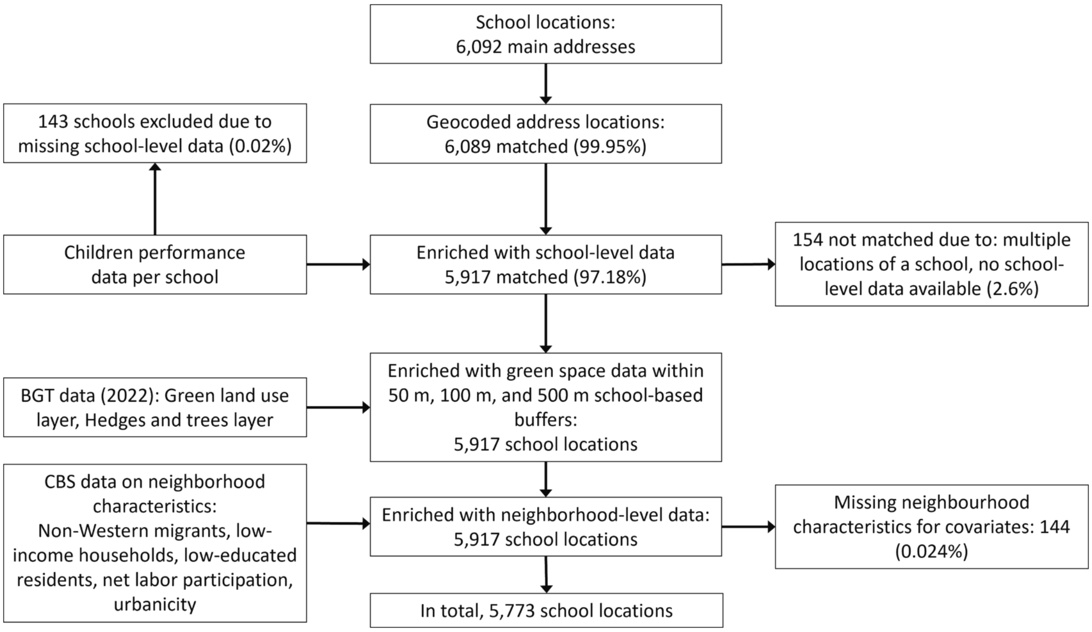

Fig. 1. School data enrichment and pre-processing.

remote sensing data (Helbich, Poppe, Oberski, Zeylmans van Emmichoven, & Schram, 2021). The large-scale base map of the Netherlands ('Basisregistratie Grootschalige Topografie') provides the most accurate data representing geometric objects (e.g., buildings) with a spatial resolution of 20 cm of homogeneous quality across the country. As such, it is an advancement on most earlier studies that used remotely sensed imagery of lower resolution to map small green spaces (Fernández et al., 2022).

Green spaces can differ in their qualities; however, the literature on the benefits of such differing green space types requires further development. To address this, we developed a high-resolution composite measure. This measure was based on z-scoring and summing the size of the available grassland (in m^2), the length of hedges and bushes (in m), and the number of trees across land use types; each providing important ecosystem services (Remme et al., 2021). The data were extracted from the layers within each buffer centered on each school location. Higher scores indicated higher levels of greenness, whereas lower scores indicated less green outdoor school environments. To delineate the geographic context, we employed concentric buffers with radii of 50 m, 100 m, and 500 m superimposed on each school location. Due to a lack of consensus on a buffer distance threshold, previous studies guided our choices (Baró et al., 2021; Fernández et al., 2022). While the 50 m buffer corresponds to the green space children experience in the schoolyard (Matsuoka, 2010), the larger buffers correspond to the broader school environs.

2.4. Covariates

We controlled for school size at the individual school level using enrollment data from the DUO database (Kuo, Klein, Browning, & Zaplatosch, 2021; Kweon et al., 2017). Additionally, guided by the available evidence base and data availability, we collected data on six neighborhood-level covariates for the year 2019 from Statistics Netherlands. Since green space exposures vary across socioeconomic strata (Baró et al., 2021; Schwarz et al., 2015; Zhang et al., 2022) and there is no universal measure available (Hajat, MacLehose, Rosofsky, Walker, & Clougherty, 2021), we included, first, the percentage of lower educated people (e.g., having primary school, pre-vocational secondary education) per neighborhood. Second, we included the percentage of low-income households. We used a threshold value of <€9,249 per year corresponding to the purchasing power of those receiving social assistance (Statistics Netherlands, 2019). Third, we included the net labor participation to represent the share of each neighborhood's residents aged between 15 and 75 years participating in the labor force. Fourth, we adjusted for ethnicity through the percentage of the neighborhood's residents with a non-Western migration background (i.e., Turkey, Africa, Latin America, and Asia [excluding Japan and Indonesia]) (Baró et al., 2021; Matsuoka, 2010). Fifth, since studies stressed disparities in green spaces and school segregation across urban, suburban, and rural areas (Logan & Burdick-Will, 2017), we included the level of urbanicity. Based on all address locations, independent of their functional use (e.g., residential, shopping), urbanicity was categorized into five classes: very strongly urban (>2,500 addresses/km^2), strongly urban (>1,500–2,500 addresses/km^2), moderately urban (>1,000–1,500 addresses/km^2), minimally urban (500–1,000 addresses/km^2), and non-urban (<500 addresses/km^2). For an in-depth description of these five covariates, see Statistics Netherlands (Statistics Netherlands, 2019). Sixth, to adjust for geographic variation and the availability of green schoolyard subsidies, we included a categorical variable capturing whether incentive schemes were available, in preparation, or no incentives were in place yet.

2.5. Statistical analyses

We chose greenness within the 50 m buffer as our prime analytical scale following previous practice (Dadvand et al., 2015). We used descriptive statistics (i.e., mean, SD, percentage) to summarize the data. Pairwise Spearman's correlation coefficients (r) were used to examine bivariate associations between the covariates. The p-values were adjusted to account for multiple hypotheses testing (Holm, 1979).

We initially fitted a linear regression using ordinary least squares (OLS) as a base model to assess the associations between school greenness and the covariates. Because the dependent variable (i.e., school greenness) was highly skewed, we applied a log transformation after adding a constant of 2 to shift the values from negative to positive. Multicollinearity was assessed by computing variance inflation factors (VIF). Following the literature (Craney & Surles, 2002), VIF values > 5 were considered to provide evidence for multicollinearity.

To assess the degree of residual spatial autocorrelation in the OLS model, we used the Moran's I ranging from -1 to $+1$ (Bivand, 2022). Positive values refer to positive autocorrelation, negative values to negative autocorrelation, and values near 0 refer to no geographic patterns in the residuals (Arbia, 2014). Statistical significance was tested using 499 Monte-Carlo simulation runs. We employed spatial econometric modeling in cases where we observed significant residual patterns, which violated the OLS-based spatially independence assumption (Anselin, 2002). We conducted robust Lagrange multiplier (LM) tests to decide whether the spatial lag or the spatial error model was most appropriate for our data (Anselin, 2002). Similar models were applied in previous studies addressing distributional green space inequalities (Schwarz et al., 2015; Zhang et al., 2022). Competing lag and error models were additionally compared with the Akaike information criterion (AIC). Lower scores indicated better goodness of fit.

Due to the spatial autoregressive setting of the lag model, the estimated parameters should not be interpreted as per normal practice (Arbia, 2014; Bivand, 2022). Three impact measures were determined: a) average direct impact (i.e., the average of a one-unit covariate change on the outcome), b) average indirect impact (i.e., the average impact of one's neighbours on one's outcome), and c) the average total impact (i.e., the total of direct and indirect impacts of a covariate on one's outcome). The spatial analyses were set up using k-nearest neighbors weight matrices to avoid isolated observations without any neighbors. To determine a suitable value for k, we tested 4 to 15 neighbors. Guided by the best model fit (i.e., lowest AIC score) and non-sensitive parameter estimates, we deemed $k = 10$ to represent an appropriate value.

We conducted multiple sensitivity analyses to confirm the robustness of our modeling results. The following tests were performed: first, we refitted the models using distance-based spatial weights of 12 km. This distance threshold was chosen by application of our descriptive statistics to the weight matrix while avoiding isolates that may cause problems in calculating spatially lagged variables. Second, models were refitted using data based on circular buffers of 100 m and 500 m. Both buffer widths allowed us to incorporate the wider geographic setting of the school environment. All analyses were performed using the R software, version 4.1 (R Core Team, 2022), and the packages 'ggplot2' (Wickham, 2009), 'spdep', and 'spatialreg' (Bivand, 2022).

3. Results

3.1. Distributional green space patterns and descriptive statistics

Unless otherwise stated, the reported results were based on 50 m school buffers. Fig. 2 depicts the geographic distribution of green school outdoor environments in the Netherlands. School-based greenness appeared to be quite unevenly distributed, with the central and western parts of the country exhibiting substantially higher scores. A substantial number of schools demonstrated little greenness. Further, a statistical assessment of the greenness pattern indicated positive spatial autocorrelation (Moran's $I = 0.323$, $p = 0.002$).

Summary statistics describing each covariate are provided in Table 1, and Supplementary Figures S1-S2 illustrate their spatial distribution. An initial visual assessment showed that the school locations with high and low greenness were distributed across high and low socio-economic

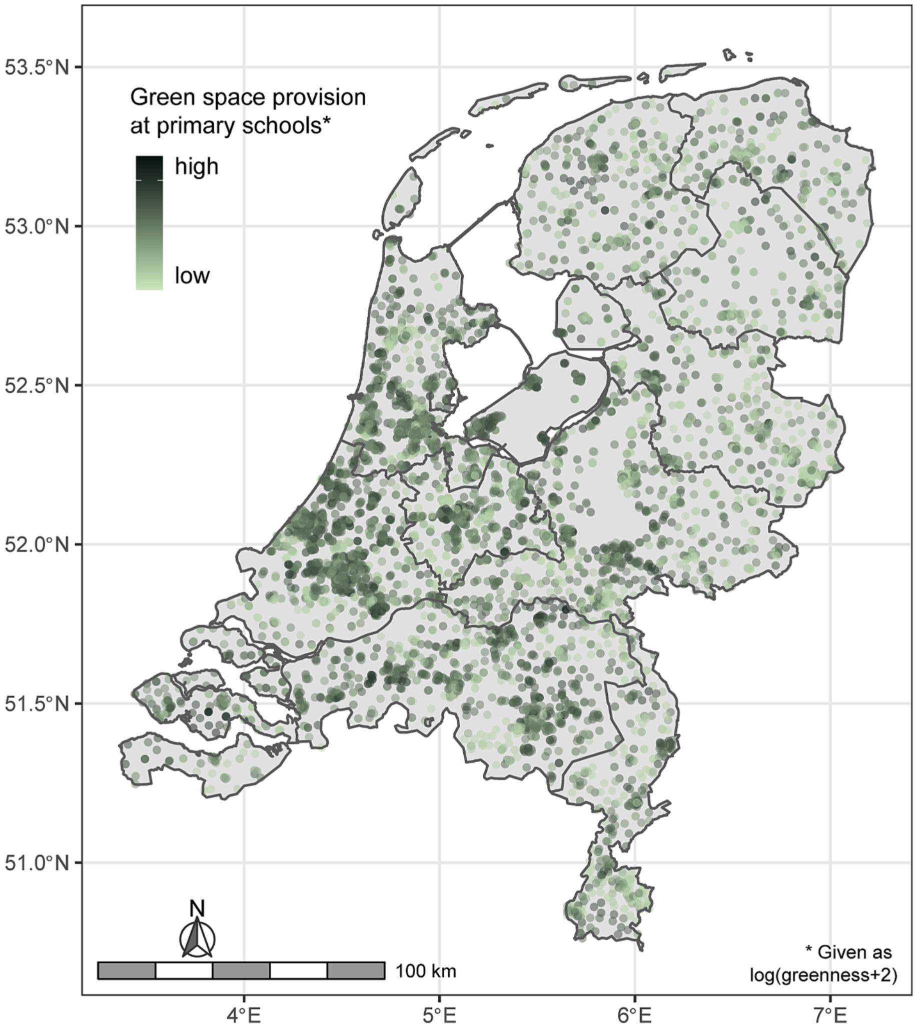

Fig. 2. Green school outdoor environments across the Netherlands. Green space provisions were based on 50 m buffers centered on school address locations.

Table 1
Descriptive statistics (based on 50 m school buffers) ($N = 5{,}773$).

Variables	Mean (SD)	%
Green spaces (log[greenness *z*-scores + 2])	0.290 (0.937)	
Non-Western migrants (%)	11.335 (13.709)	
Net labor participation (%)	69.113 (6.695)	
Low-income households (%)	6.719 (4.849)	
Low-educated residents (%)	21.992 (6.695)	
Total number of students	227.059 (136.592)	
Urbanicity: Very strongly urban		15.7
Strongly urban		24.0
Moderately urban		19.5
Minimally urban		18.2
Non-urban		22.6
Subsidies: Incentive scheme		56.3
Scheme in preparation		27.1
No incentive scheme		16.6

status areas alike. As expected, some covariates showed striking differences between urban and rural areas (e.g., % of non-Western migrants). To further assess whether there were disparities in green space around schools, we divided green space provision into quintiles (Fig. 3) based on the socio-economic covariates. Across these greenness quintiles, the proportion of net labor participation and low-educated residents was quite stable. The gradient for both the proportion of low-income households and non-Western migrants increased from the 1st quintile to the 4th but decreased thereafter. A further stratification which considered urbanicity largely replicated these results (Supplementary Figure S3).

3.2. Bivariate correlations

Fig. 4 summarizes the pair-wise correlation coefficients (r). Overall, school-level greenness and the covariates were only weakly correlated. Significant positive associations were observed with the percentage of non-Western migrants ($r = 0.164$, $p < 0.001$) and the number of students ($r = 0.054$, $p < 0.001$). Urbanicity was inversely associated with greenness ($r = -0.137$, $p < 0.001$). By contrast, net labor participation, percentage of low-educated residents, and percentage of low-income households did not reach statistical significance.

3.3. Associations with socioeconomic and geographic covariates

There was no indication of covariate multicollinearity. With a highest VIF value of 3.978, no variable exceeded a critical VIF value of 5 (Craney & Surles, 2002). The histogram of the OLS residuals followed a normal distribution, but the residuals indicated spatial autocorrelation (Moran's $I = 0.284$, $p = 0.005$), thus violating the model assumption of geographic residual independence. Based on the significant robust LM test statistics (LM = 53.662; $p < 0.001$), we decided to fit a spatial lag model resulting in the lowest p-value. AIC scores also indicated better performance of the lag model (AIC = 14,127) compared to the OLS model (AIC = 15,368) and the error model (AIC = 14,143).

Table 2 shows the resulting parameter estimates of the regression models. Not only did the spatial lag model result in fewer significant variables than the non-spatial OLS model, but also the magnitude of the estimated coefficients was partly attenuated, or variables turned out to be insignificant (e.g., urbanicity). We elaborate below on the average direct impacts, which is comparable to the traditional interpretation of associations (for the other two impact measures, see Table 2). The lag model indicated that lower educated residents ($\beta = -0.007$, $p < 0.001$) and low-income households ($\beta = -0.012$, $p < 0.050$) were negatively associated with logged greenness. Similarly, the total number of students was inversely associated, but the effect size was close to zero ($p < 0.050$). We observed a positive and statistically significant association for the percentage of non-Western migrants ($\beta = 0.009$, $p < 0.001$). There were no statistically significant greenness-urbanicity associations.

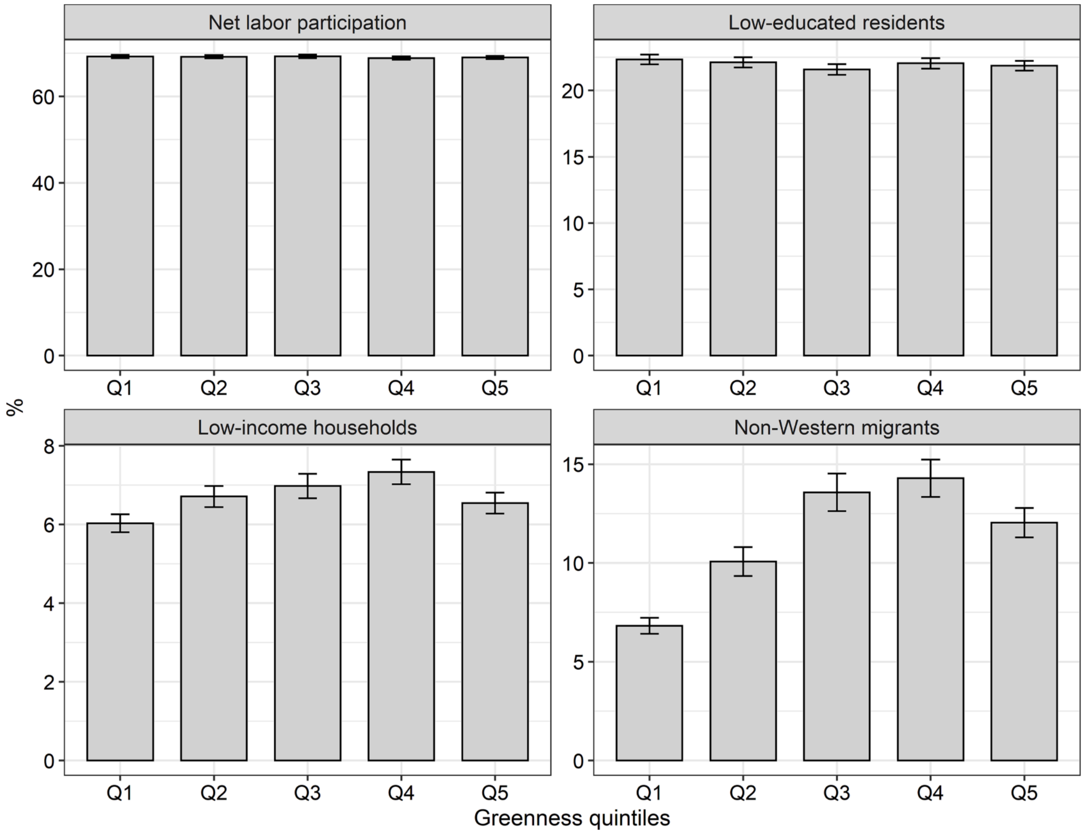

Fig. 3. Mean provision of green spaces around schools (log[greenness *z*-scores + 2]) per quintile (1 = low, 5 = high). Bars show the 95 % confidence intervals.

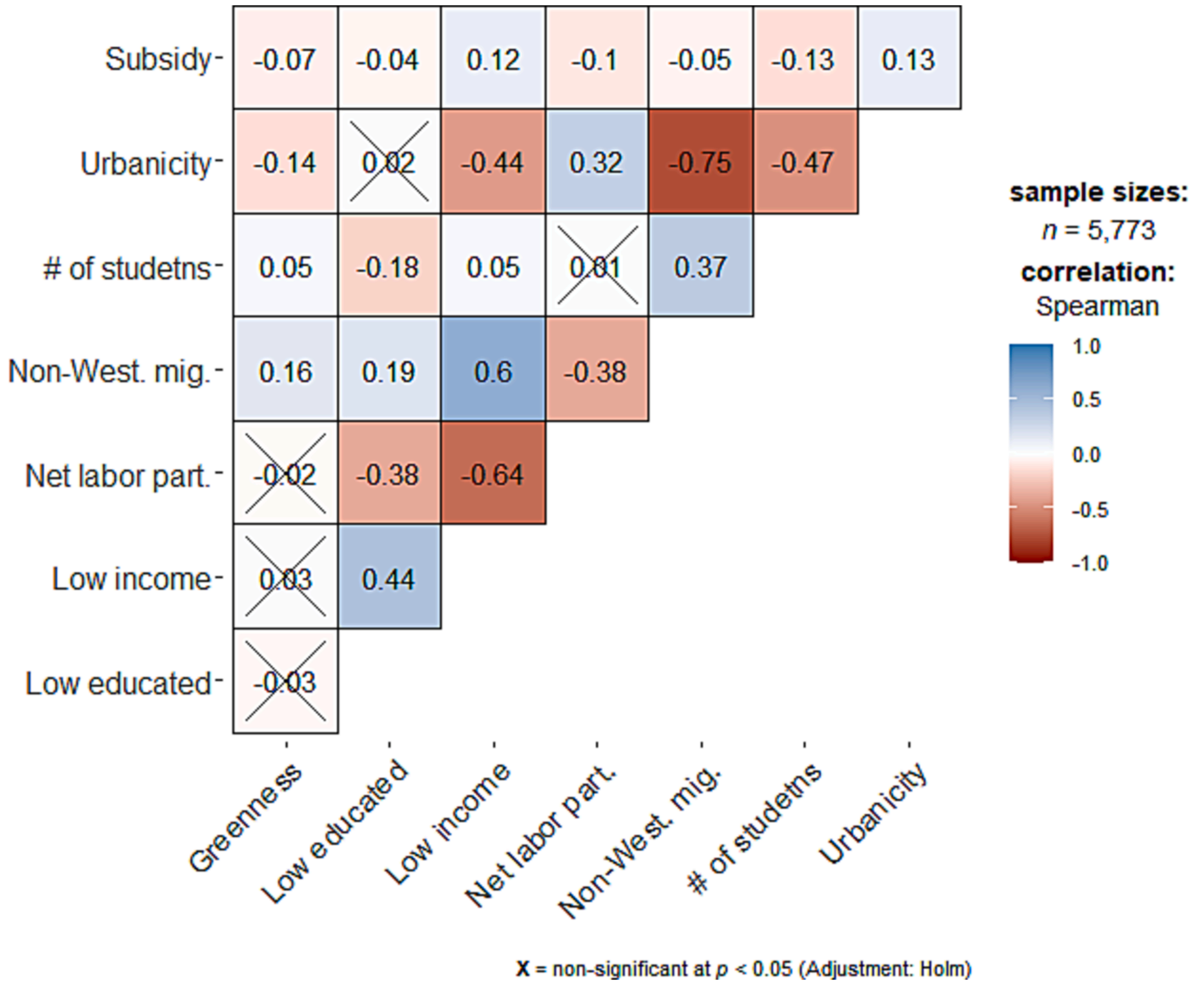

Fig. 4. Results of the pair-wise correlation analyses. Insignificant correlations ($p > 0.05$) are crossed out. The p-values were adjusted for multiple hypotheses testing. The unordered categorical variable 'subsidies' was excluded; urbanicity was considered continuously.

Schools in provinces with an incentive scheme for green schoolyards under preparation were less green ($\beta = -0.070$, $p < 0.010$) than schools in provinces with an incentive scheme. The coefficient for the no subsidy scheme did not reach statistical significance ($\beta = -0.024$, $p = 0.474$). It was not surprising that our multivariate analyses did not fully replicate the results of the bivariate correlations (Schwarz et al., 2015). That some covariates (e.g., % low-income households) showed null associations in Fig. 3 and turned significant after covariate adjustments (e.g., % low-educated residents) (Table 2) underscores the meaningfulness to account for spatially correlated socio-economic neighborhood circumstances.

3.4. Sensitivity tests

Our robustness tests evidenced that our model results were not sensitive to changes in the analytical setting. For example, neither re-estimating the spatial lag model with slightly different values for the k-nearest neighbor matrix (i.e., $k = 4$, $k = 6$, $k = 8$, and $k = 15$) nor using a distance-based weights matrix ($d = 12$ km) altered findings substantially (Supplementary Table S1). Likewise, assessing green school outdoor environments with 100 m and 500 m buffers yielded parameter estimates for the spatial lag models comparable in magnitude to those based on the 50 m buffers (Supplementary Table S2). The number of students was marginally significant in the 50 m model and significant in the 500 m model, in contrast with the 100 m model, which did not demonstrate statistical significance. While urbanicity was insignificant in the 50 m model, when buffer sizes were increased, we noted that the association became increasingly pronounced.

4. Discussion

Sustaining green space exposure for children remains high on policy agendas, but their implementation does not always follow equitable and healthy designs (Jennings et al., 2012; Rutt & Gulsrud, 2016). However, the need to provide inclusive and accessible green spaces for all children is not only explicated in the literature highlighting problems with environmental disparities in school-based greening (Rigolon et al., 2018) but is also emphasized in target #11.7 in the Sustainable Development Goals (United Nations, 2022). Our timely national study examined whether green school outdoor environments in the Netherlands faced geographic or socioeconomic inequalities.

4.1. Main findings and interpretation

The multivariate results supported our first hypothesis that green school outdoor environments are less prevalent in areas of lower socioeconomic status than in areas of higher socioeconomic status. We observed negative associations between low-income households and less-educated residents with school greenness. A Brazilian study, the only other nationwide assessment we know of, also found that neighborhood socioeconomic characteristics drive school-related green space exposures (Requia et al., 2022), while a study in North Carolina (United States) reported null associations (Zhang et al., 2022). More specifically, our findings also corroborated the results of a study in Barcelona (Spain)

Table 2
Regression results of the OLS and spatial lag model ($N = 5{,}773$).

	OLS model:	Spatial lag model:			
	β (*t*-values)	β (*z*-values)	Average direct impacts	Average indirect impacts	Average total impacts
Intercept	0.658 ** (3.242)	0.403 * (2.261)			
Low-educated residents (%)	−0.008 *** (-3.410)	−0.007 ** (-3.224)	−0.007	−0.011	−0.017
Low-income households (%)	−0.030 *** (-6.106)	−0.011 * (-2.522)	−0.012	−0.018	−0.029
Net labor participation (%)	−0.000 (-0.181)	−0.001 (-0.654)	−0.002	−0.002	−0.004
Non-Western migrants (%)	0.018 *** (11.791)	0.009 *** (6.478)	0.009	0.014	0.024
Total number of students	−0.0001 (-1.430)	−0.0001 * (-2.543)	−0.0002	−0.0004	−0.0006
Urbanicity: Strongly urban (ref. = very strongly urban)	0.013 (0.298)	0.033 (0.871)	0.035	0.054	0.089
Moderately urban	−0.136 ** (-2.750)	−0.018 (-0.419)	−0.019	−0.029	−0.048
Minimally urban	−0.167 ** (-3.148)	−0.047 (-1.016)	−0.050	−0.076	−0.127
Non-urban	−0.156 ** (-2.719)	−0.023 (-0.463)	−0.025	−0.038	−0.062
Subsidy scheme: in preparation (ref. = incentive scheme)	−0.145 *** (-5.071)	−0.066 ** (-2.619)	−0.070	−0.107	−0.177
No subsidy scheme	−0.036 (-1.004)	−0.023 (-0.717)	−0.024	−0.037	−0.061
Rho		0.626 *** (40.843)			
Adjusted R^2	0.048				
Pseudo R^2		0.234			
AIC score	15,368	14,127			

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

that also reported that schoolyards located in wealthier urban areas tend to be greener (Baró et al., 2021). In Chicago (United States), urban public schools with high percentages of economically disadvantaged students had less tree cover than those serving more socioeconomically advantaged neighborhoods (Kuo et al., 2018). Finally, earlier studies repeatedly found that the greenness levels of entire neighborhoods, on average, are higher in wealthier areas (Jennings et al., 2012; Landry & Chakraborty, 2009). Our analyses only included public schools in the Netherlands and did not include Dutch schools that are private due to a lack of data (personal communication, DUO). However, as private schools comprise only approximately 1 % of all schools, our results are likely robust. Given that we only assessed Dutch public schools, we must consider that results may differ for other school types. For example, a study in Santiago de Chile reported that private schools were considerably greener than public ones (Fernández et al., 2022).

Surprisingly, we did not find evidence that the percentage of non-Western migrants present in neighborhoods was negatively associated with school greenness, which contrasts with results from other countries. For example, studies in the United States showed that schools serving more non-White students had fewer green schoolyards in Chicago (Kuo et al., 2018), while elementary schools in Washington D.C. had fewer trees (Kweon et al., 2017). Similarly, the greenest schools in highly segregated Barcelona were found in the wealthiest districts with a low share of immigrants (Baró et al., 2021). However, in support of our results, Zhang et al. (2022) found no relation between schoolyard green spaces and students' racial or socioeconomic composition. In our data, however, the average share of non-Western migrants was 11.3 % (SD ± 13.7), relatively low compared to the United States, possibly contributing to this unexpected finding. As the observed insignificant urbanicity associations suggested, green schools are not necessarily organically aligned with more rural and greener environments, as expected from earlier work (Hodson & Sander, 2017). This refutes our second hypothesis.

As anticipated, we found confirmation of our third hypothesis that schools in provinces with a current incentive scheme for schoolyard greening were significantly greener than others. Due to the limited availability of quantitative evidence, the general effects of such policies remain uncertain. Our results were, however, substantiated by the results of two Dutch green schoolyard initiatives in Amsterdam and The Hague, stressing the effectiveness of greening incentive schemes in the school context (Giezen & Pellerey, 2021). These findings suggest that such policies might be powerful means to address green space inequalities (Stevenson et al., 2020).

4.2. Recommendations for policymakers

The findings of our study hold value for policymakers. Implementing green spaces as a nature-based strategy (Dorst, van der Jagt, Raven, & Runhaar, 2019) in the environs of primary schools in less well-off neighborhoods may be a viable and cost-effective method to address green space inequity. It is certain that, location-independent minimum standards for the provision of green space should be integrated into all school systems. Implementing such standards might assist in offsetting the advantages that currently accrue only to children in wealthier neighborhoods, often characterized by the provision of more and better public parks (Wolch, Wilson, & Fehrenbach, 2005). It would also be a step towards tackling green space distributional injustices. Marginalized and vulnerable neighborhoods are also likely in greater need of the consequent health benefits (Rutt & Gulsrud, 2016). From an ecological viewpoint, green spaces provide ecosystem services (Veerkamp et al., 2021) critical for climate resilience and healthier and safer environments for children, among other things (Flax, Altes, Kupers, & Mons, 2020). Thus, policymakers and planners should not stand on a status quo that only favors the socially advantaged but provide environmental 'goods' to all (Pearce, Richardson, Mitchell, & Shortt, 2010).

While the Dutch subsidy schemes seem likely to reach their targets, these policies are currently being implemented and managed at the provincial level, leaving behind those not covered by such greening subsidy schemes. We advocate for national-level action targeting environmental equity by the provision of equal access to financial resources to facilitate the transition from grey to green schoolyards and to ensure equal provision for all (Giezen & Pellerey, 2021). Such comprehensive approaches seem particularly relevant to those schools with lower resource availability serving lower socioeconomic status neighborhoods (Owens & Candipan, 2019). However, the experience of the Amsterdam and The Hague green schoolyard initiatives was that even co-funded, the required installment and maintenance costs were not always easily accessible due to financial and social inequalities across schools (Giezen & Pellerey, 2021). Furthermore, ongoing community buy-in to support maintenance could also be a challenge. These considerations were found to be of particular concern for schools in the poorest districts. As the resource demands for upscaling to green schoolyards appear to be non-trivial, and specific barriers need to be overcome, addressing these barriers calls for transdisciplinary research to support evidence-based policies and a governance approach including all stakeholders (e.g., the public and private sectors, urban designers, and local citizens) (Stevenson et al., 2020).

4.3. Strengths and limitations

This study possesses several strengths. To the best of our knowledge, it is the first to discuss inequalities in schoolyard greenness in the Dutch context and is among the largest of its kind. In contrast to much of the available evidence focused on urbanized areas (Giezen & Pellerey, 2021; Van Dijk-Wesselius et al., 2018), our study was enriched by including rural and suburban areas, which led to a greater diversity of sociodemographic profiles. Second, given a lack of a universally accepted metric for greenness assessments, we strengthened the evidence base by considering green space qualities, which, although treated as a composite measure, was very fine-grained (e.g., individual trees, length of hedges). Such qualities would otherwise remain unrecognized in nationwide analyses that exclusively used remotely sensed imagery due to constraints caused by minimum mapping units, cloud cover, and similar factors. Our approach circumvents methodological issues that the satellite-based Normalized Difference Vegetation Index may not adequately capture in terms of the small-scale green spaces that schoolchildren experience. Whether our greenness metric closely describes how children perceive eye-level vegetation on-site remains an open question (Helbich et al., 2021).

Although our analyses advanced methodologically and conceptually on previous analyses, we need to emphasize certain limitations, typical in studies such as ours. First, our green space data did not precisely match the year of the school data. Due to this temporal misalignment, we cannot exclude the possibility of contextual uncertainties that might have affected the reported regression estimates (Helbich, 2019). However, we believe such influences can be ignored in this case due to school locations and neighborhood compositions remaining relatively stable within the two-year-long observation period. Second, when interpreting our results, it is imperative to realize that our green space metric captured only green space provision and not whether green space was accessible and used by children. Whether direct measurement of the factors of accessibility and use by children would yield similar results remained unanswered. Third, although our regressions thoroughly incorporated spatial autocorrelation, model examination suggested the existence of a minimal degree of heteroskedasticity. It is likely due to fitting a single regression for the whole country with uniform coefficients. While models like ours are widely applied in nationwide analyses, we advise future studies to explore spatial non-stationarity in the regression parameter through spatially varying coefficient models. Fourth, an additional point to consider when interpreting our findings is the context of our study and its transferability to other countries. The Netherlands is very densely populated and highly urbanized; thus, its educational policies and the distribution of primary schools may differ from those of other countries. Fifth, although we selected our covariates with care based on the prior literature, we cannot rule out that others might have been missed. For example, the variable, which captured whether incentive schemes were in place, was only available at the province level. We lacked school-specific data on when and in which year the school had implemented the green schoolyard subsidy schemes. Sixth, our study design based on area-level data prevented us from drawing conclusions on the individual level, and our reported associations could be sensitive to changes in the analytical scale beyond the assessed buffer widths. Moreover, we could not exclude the possibility that using the intersection of buffer data with area-level data to obtain school-specific neighborhood profiles could create another source of bias in our statistical analysis (modifiable areal unit problem). Lastly, as inherent in every cross-sectional research on green spaces, our results are susceptible to reverse causalities – a limitation that applies to most previous studies as well (Baró et al., 2021; Kweon et al., 2017). To alleviate this shortcoming in future studies, we advise such studies to be longitudinal or quasi-experimental to establish a more causal understanding of green space inequalities.

5. Conclusions

School-based green spaces provide critical ecosystem services (e.g., heat mitigation, stress reduction) supporting children's health, but due to an uneven distribution geographically and socioeconomically, not all children benefit equally. As a result, children in neighborhoods of lower socioeconomic status may experience environmental injustice. Our cross-sectional findings from the Netherlands support this notion, finding that schools tend to be less green in neighborhoods of lower socioeconomic status than those of higher socioeconomic status. Furthermore, the disadvantage experienced by children from lower socioeconomic status neighborhoods may be exacerbated in Dutch provinces that possess such neighborhoods but do not provide subsidy schemes for green schoolyards. A consequence of this is that schools (even in highly urbanized areas) that do receive subsidies tend to be greener than those in areas without subsidies.

Greenness at school appears to be, at least in part, a policy choice. Thus, policy action at the national level is indicated to foster a higher degree of environmental justice for Dutch schoolchildren, and we urge policymakers to support policies that promote equality of schoolyard greening outcomes for all Dutch schoolyards. Society is responsible for providing children opportunities to incorporate nature into daily lives mainly spent at school.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.landurbplan.2023.104687.

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